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RESEARCH ARTICLE

LabVIEW BASED COST EFFECTIVE SIMULTANEOUS DATA ACQUISITION SYSTEM: MEASUREMENT OF C-V OF THE FERRITE THIN FILMS

*,[1]Todkari, S.M., [2]Bachuwar, V.D. and [3]Salunke, D.J.

[1]Department of Electronics, Sangmeshwar College, Solapur-413001, M.S. India
[2]Department of Electronic Science, Solapur University, Solapur-413255, M.S. India
[3]Department of Physics, KBP College, Pandharpur-413304, M.S. India

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ABSTRACT

The main purpose of work is to develop low cost and portable PC interfaced data acquisition and monitoring system especially for C-V measurement of the ferrite thin films. Data acquisition system (DAS) consist of microcontroller AT89S52, Two ADC (0804) and DAC as sweep generation for C-V measurement, data acquisition system must acquire two parameters simultaneously i.e. cos wave reference signal and sin wave reference signal which incorporates phase and amplitude information. Data acquisition system acquire serially and send to PC with LabVIEW. LabVIEW GUI is developed to process the data and display the value of phase and amplitude of waveform and other relative electrical parameters of device under test (DUT), this also utilize for simultaneous measurement of any two physical parameters in general, which is essential most of the time in the research lab, the device is able to acquire two different physical parameters at the same instant and data logging with PC using USB port and processing of the signals using LabVIEW.

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INTRODUCTION

Capacitance-voltage (C-V) testing is widely used to extract semiconductor parameters, particularly in MOSCAP and MOSFET structures. However, other types of semiconductor devices and technologies can also be characterized with C-V measurements, including bipolar junction transistors (BJTs), JFETs, III-V compound devices, photovoltaic cells, MEMs devices, organic TFT displays, photodiodes, carbon nanotubes (CNTs), Ferrite Thin Films and many others. The fundamental nature of these measurements makes them useful in a wide range of applications and disciplines. Ferrite thin films are used in the research labs of universities and semiconductor manufacturers to evaluate new materials, processes, devices, and circuits. C-V measurements are extremely important to product and yield enhancement to engineers, who are responsible for improving processes and device performance. Reliability engineers use these measurements to qualify material suppliers, monitor process parameters, and analyze failure mechanisms(Stauffer and Instruments, 2009).The dielectric constant is measured by the determination of capacitance formed using given dielectric material. Usually, the present day applications require thin film of ferroelectric/ dielectric compounds having a useful magnitude of electric tunablity (τ). Such system could be used in formation of tuneable filters, resonators etc. for both RF as well as Micro-wave frequency range. Thus the basic requirements of the measurement of the tunablity is the measurement of capacitance at certain frequency of ac excitation superimposed with a $\pm$ DC bias voltage. This successful attempt provides design of exclusive C-V meter with PC interfaced DAS, for the measurement of Capacitance with respect to D.C. bias voltage also facilitate measurement of Quality Factor, electrical tunablity, loss tangent and other electrical characteristics of thin filmsof ferroelectric/dielectric compounds specially. At present, researchers utilizes LCR Q-meter for measurement of electrical characteristics of ferro-electric/di-electric materials in laboratory, these are generalized instruments and therefore become costlier. Thus design and development of an exclusive C-V meter may offer a cost effective solution for measurement of C-V characteristics. The design may provide increased accuracy as only few parameters are the measure and for required application at limited frequencies. Here the various available schemes of C-V meter instruments are compared and a new scheme is proposed to design and develop exclusive C-V meter operating at few selected frequencies, for limited laboratory application. The novel scheme is projected to have minimum possible error in respect of amplitude as well as phase measurement. Further development of this product is

Corresponding author:* **Todkari, S. M.
Department of Electronics, Sangmeshwar College, Solapur-413001, M.S. India

expected to provide a detailed understanding for circuit design and development of variable frequency LCR-Q meter Joshi and Sciences, 2016). Thin-film of ferrites has already been commercially exploited for high-capacitance density decoupling capacitors, but the focus of attention here is on voltage tunable integrated capacitors (varactors)

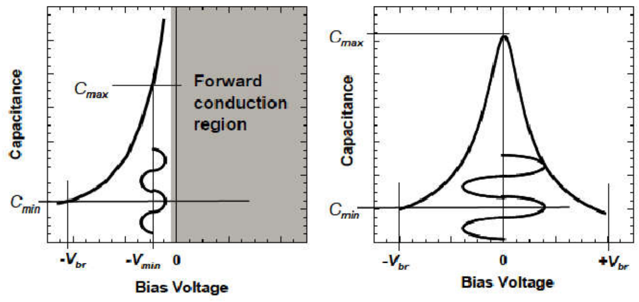

Fig.1. Comparison of diode and dielectric varicapcharacteristics. BST varactors have no forward conduction region, and hence can sustain large RF voltage swings, especially near zero volts

Now day's varactor diode are replaced by varicap at RF as well as microwave frequency range. Dielectric varicap do have one key advantage relative to diodes: there is no forward conduction region. As shown in Fig., this allows for improved power handling and simpler biasing compared with diodes. Dielectric varicap also require less sophisticated processing for a given Q-factor and operating frequency, these can be easily integrated with other high-Q passive components, factors that tend to lower overall implementation cost, now a days ferrite thin films are also used in the tunable antennas in telecommunication sector (York and York, 2009; Gundel*et al.*, 2012). Due to these versatile characteristics measurement of C-V is important characterization in ferrite thin films, to achieve this various measuring instruments are available such as Agilent, KEITHLEY, HP, Waine-kerr etc. The simultaneous data acquisition system not only uses for CV measurement but also used in automotive, medical, physical parameters in lab, observatory and nuclear research to measure different parameters (Andria *et al.*, 2016; Lin and Sriyudthsak, 2016; Haro and Arnaldi, 2016; Jiang *et al.*, 2011).

Simultaneous data acquisition system for C-V measurement for ferrite thin films consists following components:

a) DUT excitation circuit
b) Auto-balancing bridge(I to V converter)
c) Phase Sensitive Detector (PSD) (Analog Multiplier)
d) Simultaneous Data Acquisition System
e) USB interface LabVIEW
f) LabVIEW GUI (Datamanagement and processing)

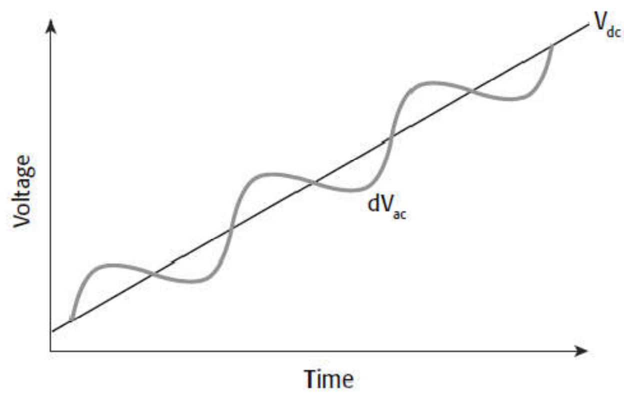

Fig. 2. b) AC and DC voltage of C-V sweep measurement

To measure C-V characteristics ferrite thin films two simultaneous voltage sources an applied AC voltage signal (dVac) and a DC voltage (Vdc) that is swept in time, as illustrated in Fig 2 b). The magnitude and frequency of the AC voltage are fixed; the magnitude of theDC voltage is swept in time. The purpose of the DC voltage bias is to allow sampling of the material at different depths in the device. The AC voltage bias provides the small-signal bias so the capacitance measurement can be performed at a given depth in the device. Signal in Fig 2 b) is obtained using adding sine wave 300mV and sweep D.C voltage of 0 to ±10V.At the same time the two square waves are generated having 0° phase difference and 90° phase difference with respect to same sin wave labelled as Sin wave reference and Cos wave reference, further these signal are given to one of the inputs of phase

C-V Measurement circuit

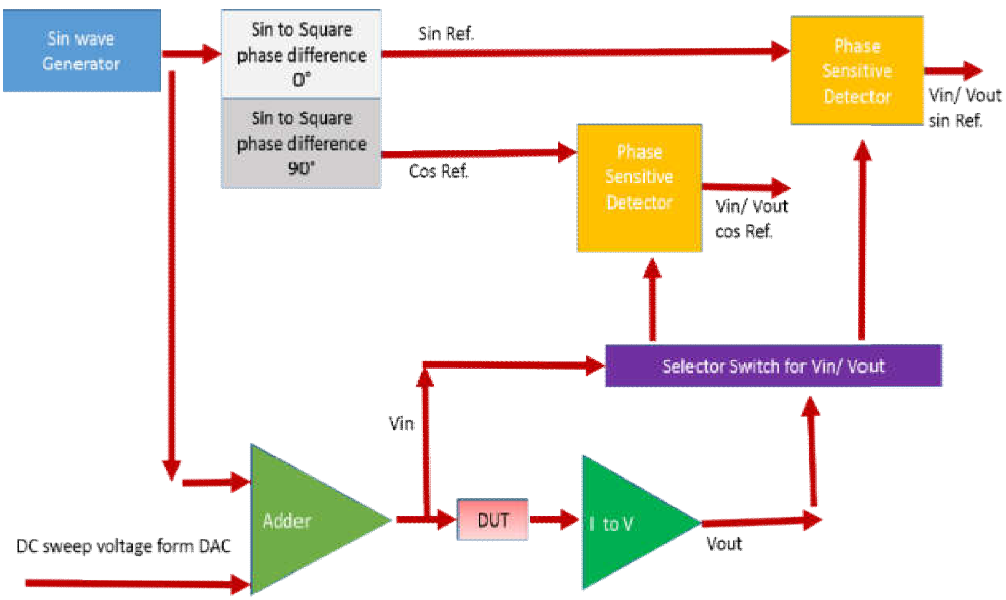

Fig. 2. a) DUT excitation circuit

sensitive detector. Phase sensitive detector consists of analog multiplier with low pass filter. A.C. signal excitation is first measured bypassing the DUT using selector switch these signal is consider as Vin sin reference and Vin cos reference for further calculations. It uses the auto-bridge balancing technique. Advantage of this technique is Wide frequency coverage up to 40 MHz, High accuracy over a wide impedance measurement range(Agilent Impedance Measurement Handbook A guide to measurement technology and techniques, 4th ed.). The DUT (i.e. thin ferro- electric film) consider as parallel combination of C_x and R_x, neglecting series resistance as it is small.

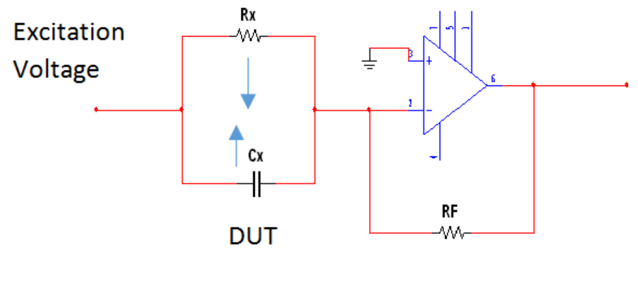

Fig.2. c) Ferrite thin films (DUT) equivalent and I to V converter circuit

The total impedance of DUT Zx is parallel combination of Rx and Cx in which series resistance is assumed to be very small; hence neglected.

$Ix = Vin / Zx$ ---------------- (1)

$Ix = Vin (Gx)= Vin (1/Rx + j\omega Cx)$------------(2)

$Vout = Vo = Ix*Rf$ -------------- (3)

$Vout = Ix* Rf = Vin Rf (1/Rx + j\omega Cx)$------------(4)
Splinting Vout into its vector components

$Vout = VosinRef + j\omega cos Ref$---------------------(5)
Comparing equations (4) and (5),

$VosinRef = Vin *Rf* (1/ Rx)$-----------------(6)

$VocosRef = Vin* Rf* \omega*Cx$-----------------(7)
Hence the component VoSinRefα 1/Rx
VoCosRef α Cx
The loss tangent
$D = \tan\partial= 1/ 2\pi f\, Cp *Rp$--------------(8)
And Quality factor
$Q = 1/D$ --------------------(9)

The accuracy in measurement of Rx and Cx achieved by using the following equations,

$Rx = Rf ((Vi_{0°})^2 + (Vi_{90°})^2) / (Vi_{0°}) * (Vo_{0°}) + (Vi_{90°}) * (Vo_{90°})$ ---------------------(10)

$Cx = (Vi_{0°})* (Vo_{90°}) - (Vi_{90°})* (Vo_{0°}) / 2\pi f *Rf ((Vi_{0°})^2 + (Vi_{90°})^2)$------------------(11)

$(Vi_{0°})$ = in-phase input signal voltage to DUT (i.e. Vin-sin ref)

$(Vi_{90°})$ = quadrature -phase input signal voltage to DUT (i.e. Vin-cos ref)

$(Vo_{0°})$ = in-phase output voltage of I to V converter (i.e. Vout-sin ref)

$(Vo_{90°})$ = quadrature -phase output signal of I to V converter (i.e. Vout-cos ref)

Rf = feedback resistor of I to V converter, f = applied input signal frequency.

Data Acquisitions System

Measurement of C-V consist of measuring a two parameters simultaneously i.e. Vout cos ref and Vout sin ref. implement a simultaneous data acquisition system here used the two ADC0804 single channel ADC with inbuilt clock and DAC0808 to control the D.C. sweep voltage to DUT, which are communicated and control by AT89S52 as shown in fig 3 (a). ADC0804 are simultaneously communicated to AT89S52 and data regarding to Vout cos ref and Vout sin ref with respect to D.C. sweep voltage is stored in AT89S52, the range of D.C sweep voltage is 0V to ±10V. Data is send serially to PC/ Laptop using serial to USB converter, which again communicated to LabVIEW GUI. In this system PC acts as master and microcontroller as slave.

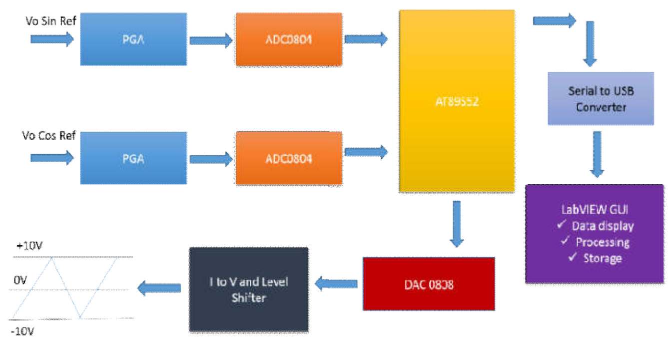

Fig. 3. (a) System Block Diagram of AT89S52 Based Data Acquisition System

Signal Conditioning for Data Converters

The signal condition circuits are used as inverting/non-inverting amplifier and programmable gain amplifier with gain 2,5,10. The Vin sin ref is negative voltage, connected to inverting while remaining connected with non- inverting amplifier with required gain. So it will in the range 0-5V essential for ADC. The DAC reference current adjusted to 2mA and feedback resistor of I to V converter is connected,so as to get output sweep voltage vary from 0 to 10V and by use of level shifter circuit the sweep voltage ±10V is provided to DUT, in 16 steps.

Simultaneous ADC 0804 and Controlling Sweep voltage of DAC0808

To executing the simultaneous ADC operation, start conversion (WR) of the both ADC0804 are connected to commonly to AT89S52 (pin P3.5) while end of conversation signal are connected as separate interrupts to microcontroller AT89S52(Pin P3.3 and P3.4 respectively), so that after receiving the interrupt microcontroller read the data from both

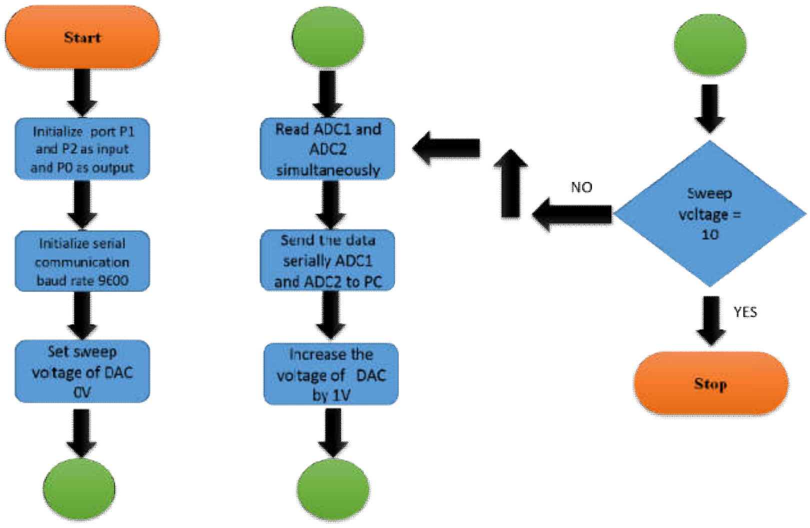

Fig. 3. (b) Algorithm of Simultaneous ADC control and Sweep voltage control

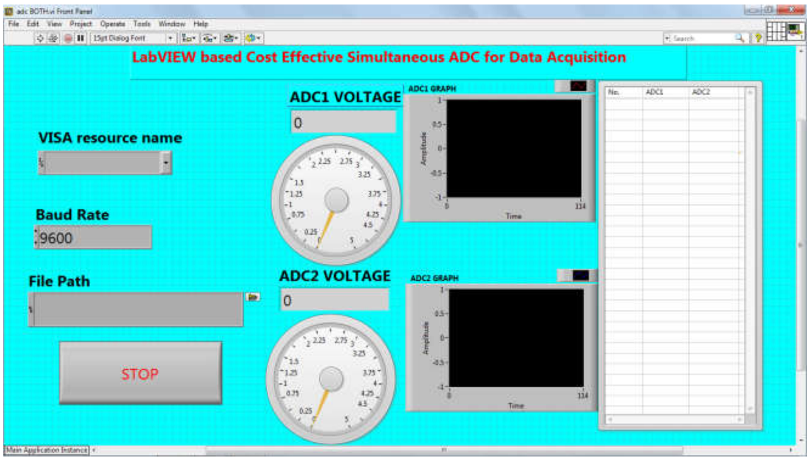

Fig. 4. a) Simultaneous ADC interface in LabVIEW

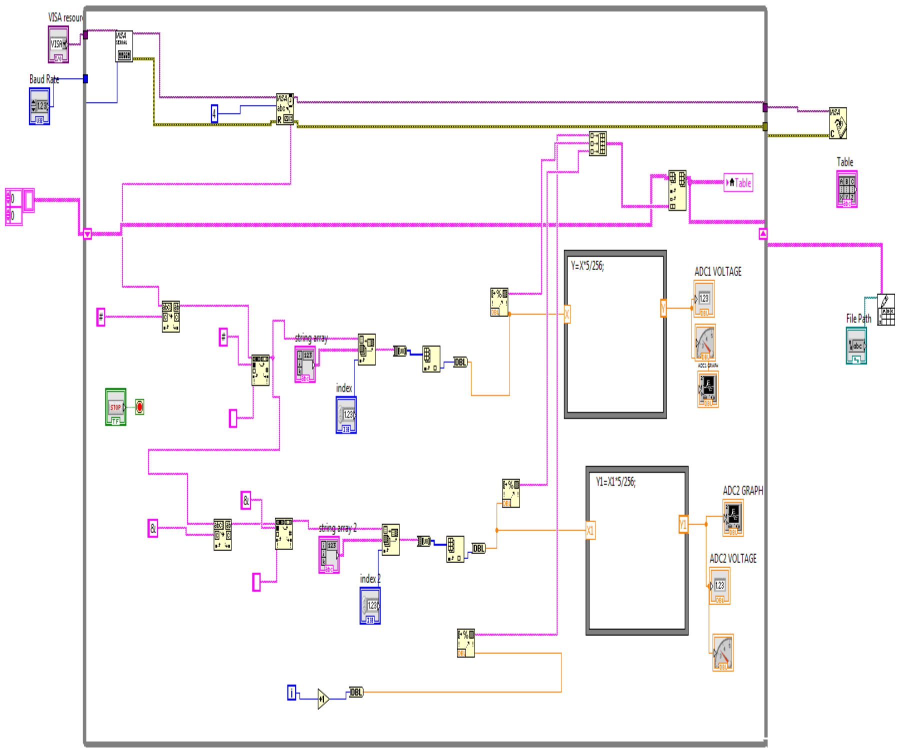

Fig. 4. b) G-code for the Simultaneous ADC interface and Data acquisition

ADC which is acquired at same time available in latch in ADC's. The algorithm for simultaneous ADC and controlling DAC sweep voltage as shown in Fig. 3(b).

LabVIEW interface and GUI

Developed GUI in LabVIEW is shown in Fig.4 a). After setting the VISA source name, baud rate (9600) and file path it will acquire the simultaneous voltages for capacitance measurement. To identify Vo Sin ref and Vo Cos ref Voltages special characters are added using.ASM file. After reading by VISA resource these characters are eliminated from the string and respective data is recovered. The LabVIEW application was veteran on a portable computer with a 2.40 GHz CPU, 4 GB DDR.

RESULTS AND DISSUASION

Set of readings are taken with standard resistance and capacitor and their pair which acts like a DUT

Standard Capacitor results:

Fig. 5 a) shows the results obtained from measurement of standard capacitor and their respective Vo COS REF, which gives 99.84% linearity in case of measurement of capacitance.

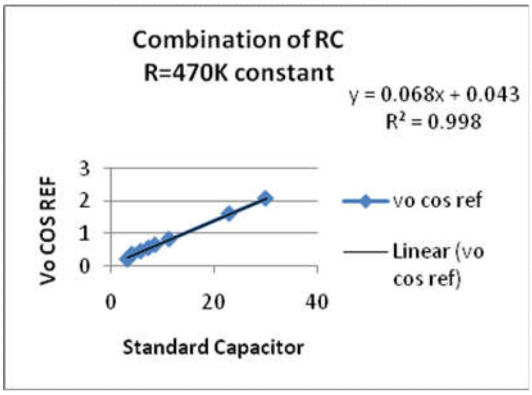

Fig.5. a) Results of capacitor in Simultaneous ADC interface in LabVIEW Results of Combination RC (R=470k)

Fig 5b) shows the results obtained from measurement of standard capacitor-resistor pair and their respective Vo COS REF, which gives 99.82% linearity in case of measurement of capacitance.

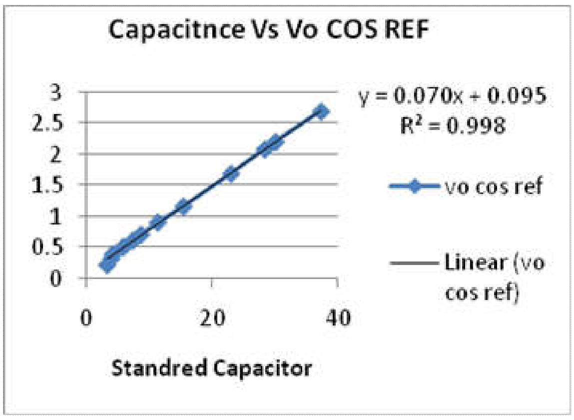

Fig.5. b) Results of combination of RC (R= 470k) in Simultaneous ADC interface in LabVIEW

Fig 5bc) shows the results obtained from measurement of conductance (1/Rx) their respective Vo Sin REF, which gives 98.96% linearity in case of measurement of conductance.

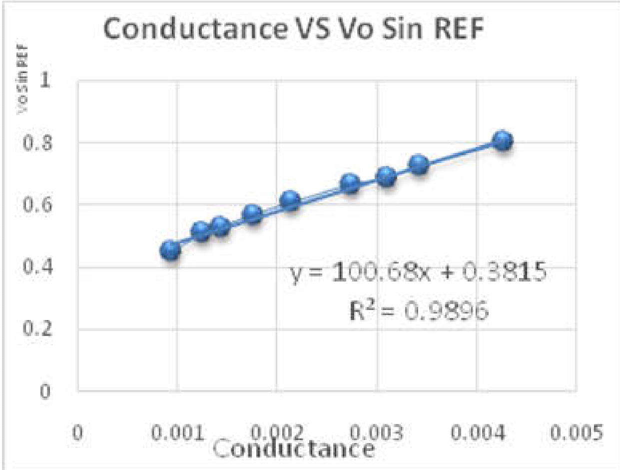

Fig.5. c) Results of combination of RC (C= 10pF) in Simultaneous ADC interface in LabVIEW

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